IMPROVEMENTS IN AUTOMATIC SAMPLING EQUIPMENT USED TO DETERMINE EXTENT OF POLLUTION IN RUNOFF FROM AGRICULTURAL WATERSHEDS

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IMPROVEMENTS IN AUTOMATIC SAMPLING EQUIPMENT USED TO DETERMINE EXTENT OF POLLUTION IN RUNOFF FROM AGRICULTURAL WATERSHEDS[1]

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Concern over the quality of water in streams, rivers, and lakes is leading to a critical evaluation of how farming practices affect the quality of water coming from agricultural lands. The movement of agricultural chemicals from fields into waterways is of special interest.

Agricultural chemicals vary widely in the way they react with the soil and move across and within it. At one extreme are those that move freely with the soil water. These are readily leached into the ground water and the streams that drain the area. At the other extreme are those chemicals that are bound tenaciously to the soil colloids. Very little leaching of these compounds occurs, but they may still be removed from the area by erosion and be transported downstream with the eroded soil material.

In the spring of 1966, an experiment was undertaken on two instrumented runoff watersheds at Coshocton, Ohio, to study the movement of dieldrin, nitrates, and phosphates downward through the soil profile and laterally across the sloping surface of the hill, and to measure the losses resulting from erosion and runoff. The Coshocton station is in an area of high-intensity summer rainstorms. These cause soil splash and severe sheet erosion. Single storms of 4 inches per hour for 15 to 60 minutes' duration have caused as much as 10 tons of soil loss from 2- to 3-acre watersheds. The soil in these watersheds is a well-drained Muskingum or slowly permeable Keene silt loam developed from residual shale or sandstone on 6- to 15-percent slopes.

In this report are described the sampling requirements as set forth in ARS 41-136[3] and improvements made since 1967 in the equipment and techniques developed at the Coshocton station to obtain samples of runoff from watersheds and preserve them for laboratory analysis. Several important design features of the automatic sampling equipment have been modified since the initial report (ARS 41-136) on this subject was published. These changes provide for more precise control of sampling sequence time, greater reliability, and lower equipment cost.

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[1]Contribution from North Appalachian Experimental Watershed, Corn Belt Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, Coshocton, Ohio, in cooperation with Ohio Agricultural Research and Development Center, Wooster, Ohio.

[2]Research soil scientist (physics), hydraulic engineering technician, and research hydraulic engineer, respectively.

[3]Harrold, L. L., Barrows, H. L., and Bentz, W. W. Automatic sampling technique to determine extent of pollution in runoff from agricultural watersheds. U.S. Dept. Agr., Agr. Res. Serv. ARS 41-136, 12 pp., illus. October 1967.

SAMPLING REQUIREMENTS

Since the runoff rate and concentration of dissolved and suspended materials vary during any given runoff, samples are required periodically throughout the runoff period. Because the greatest changes in rate of runoff and transported materials occur during the rising stages of the hydrograph, samples must be collected more frequently during this period than during recession (fig. 1). Thus the sampling equipment must be capable of collecting individual samples at variable predetermined time intervals throughout the runoff hydrograph.

The sampling equipment must operate unattended. It must remain on a standby basis, ready to operate at all times, detect initial runoff from the test watershed, and initiate and execute the programed sampling sequence. Concurrently, the runoff rate and time must be monitored and recorded in order that the relationship of each sample to the total can be evaluated.

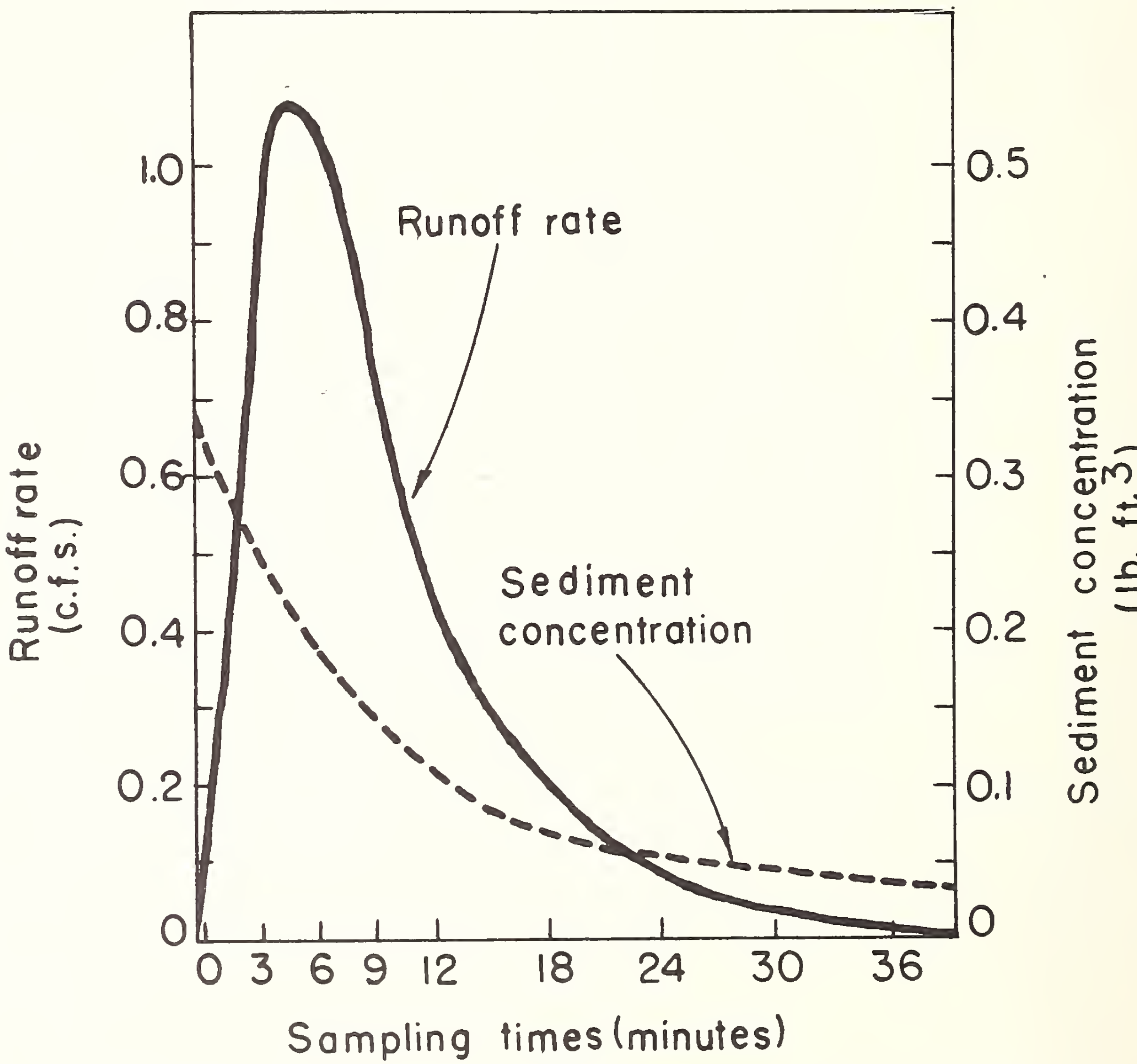


Figure 1.--Simplified runoff hydrograph and sediment load from small agricultural watersheds.

The samples must be refrigerated immediately after they are collected and kept in this condition to minimize biological, chemical, and physical changes prior to laboratory analysis. Solids separated from the sample between 16 and 48 hours after collection are frozen until analyzed.

SAMPLING EQUIPMENT IMPROVEMENTS

The following important improvements were made in the sampling equipment (fig. 2) after ARS 41-136 was issued.

1. Component parts for a liquid pump sampler can be obtained commercially and readily assembled into a workable unit (fig. 3). This unit will pump samples at predetermined time intervals as satisfactorily as the original preassembled unit shown in figure 3 of ARS 41-136 and at considerably less cost.

The new unit (fig. 3) consists of one adjustable 30-minute maximum dial timer, which defines the interval between samples; one adjustable 30-second maximum dial timer, which controls the length of time each sample valve remains open (jug filling time); and an electric pump, which delivers the sample to the sample jugs. The timers are mounted in a case, which also houses the necessary wiring and an "on-off" switch.

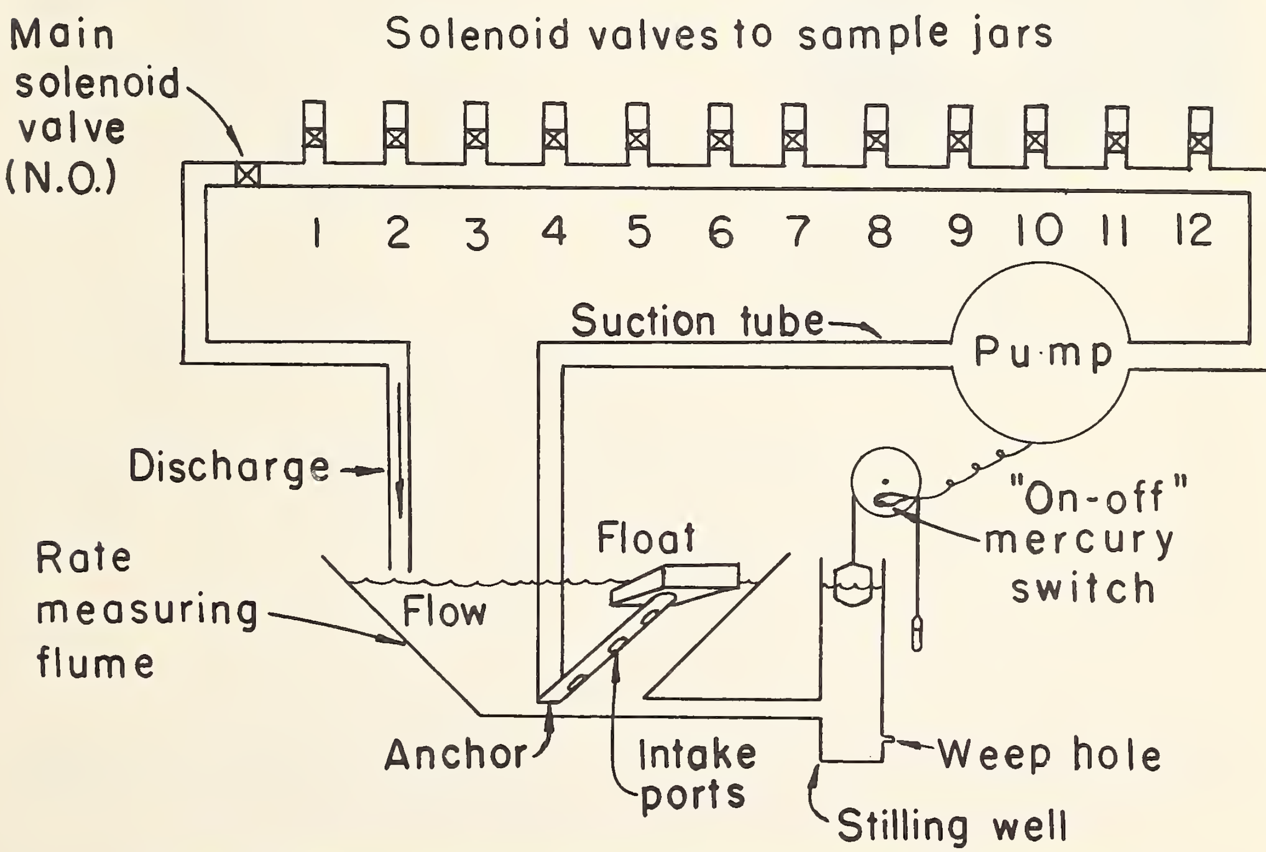


Figure 2.--Schematic of automatic hydraulic system designed to obtain 12 samples of runoff.

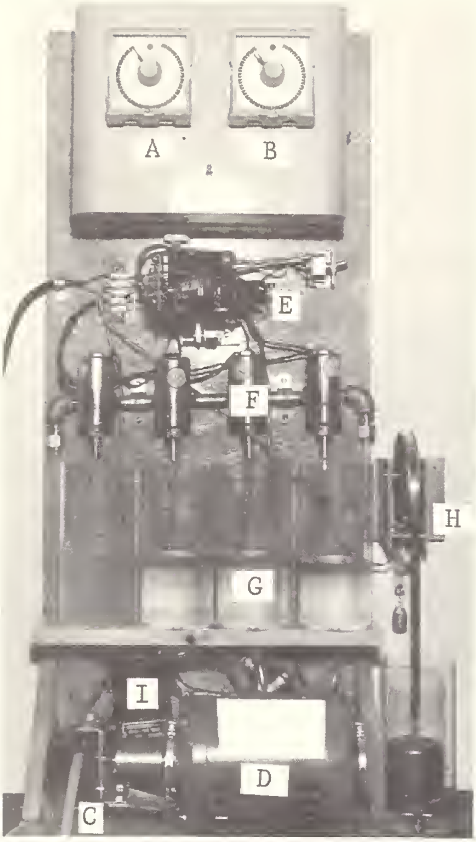


Figure 3.--Demonstration model of liquid sampler assembled from component parts. A, Interval timer (min.); B, Sample duration timer (sec.); C, Pump; D, Motor; E, Step switch; F, Sample valves; G, Sample jars; H, "On-off" mercury float switch; I, Main line valve--normally open.

The pump motor is started on signal from the first timer. After a 20-second delay, during which time the system is flushed with current runoff, the minute timer transmits power to the second timer and a sample jug is filled.

Manufacturer's descriptive literature supplied with each new timer shows circuit diagrams for various actions, control functions, adjustments, and physical data. The timers have been rewired and modified as shown in figure 4 to produce a flushing period before sampling. Figure 4 shows the complete electrical circuitry used for this sampler.

The equipment described here (timers, case, pump, and motor) could be purchased for less than $165 in 1968. The samplers used in the original installations cost about $1,000 each and performed other functions than those needed for this program. Items other than the first four in the following list must be added to the commercial unit as well as to the assembled unit.

The following is a complete list of parts for the improved liquid sampler.[4] The list gives the names and addresses of the manufacturers and the 1968 price.

Part and manufacturer	Price, 1968
Cycle-Flex reset timer (30-second dial) HP 50A	$44.50
Cycle-Flex reset timer (30-minute dial) HP 55A6-01	46.50
Dual unit case, wired, with toggle switch, HN368	30.00
Bliss-Eagle Signal, 736 Federal St., Davenport, Iowa 52803	
Jabsco pump with motor, 3/8" port size, P6M6, "Sturdi-Puppy" . .	41.25
Jabsco Pump Co., 1845 Dale Way, Costa Mesa, Calif. 92626	
Magnatrol, N.O. (normally open) valve-type, #18NR22, 3/8" valve port--1/2" pipe size	39.00
Magnatrol Valve Corp., 67 Fifth Ave., Hawthorne, N.J. 07506	

[4] Trade and company names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

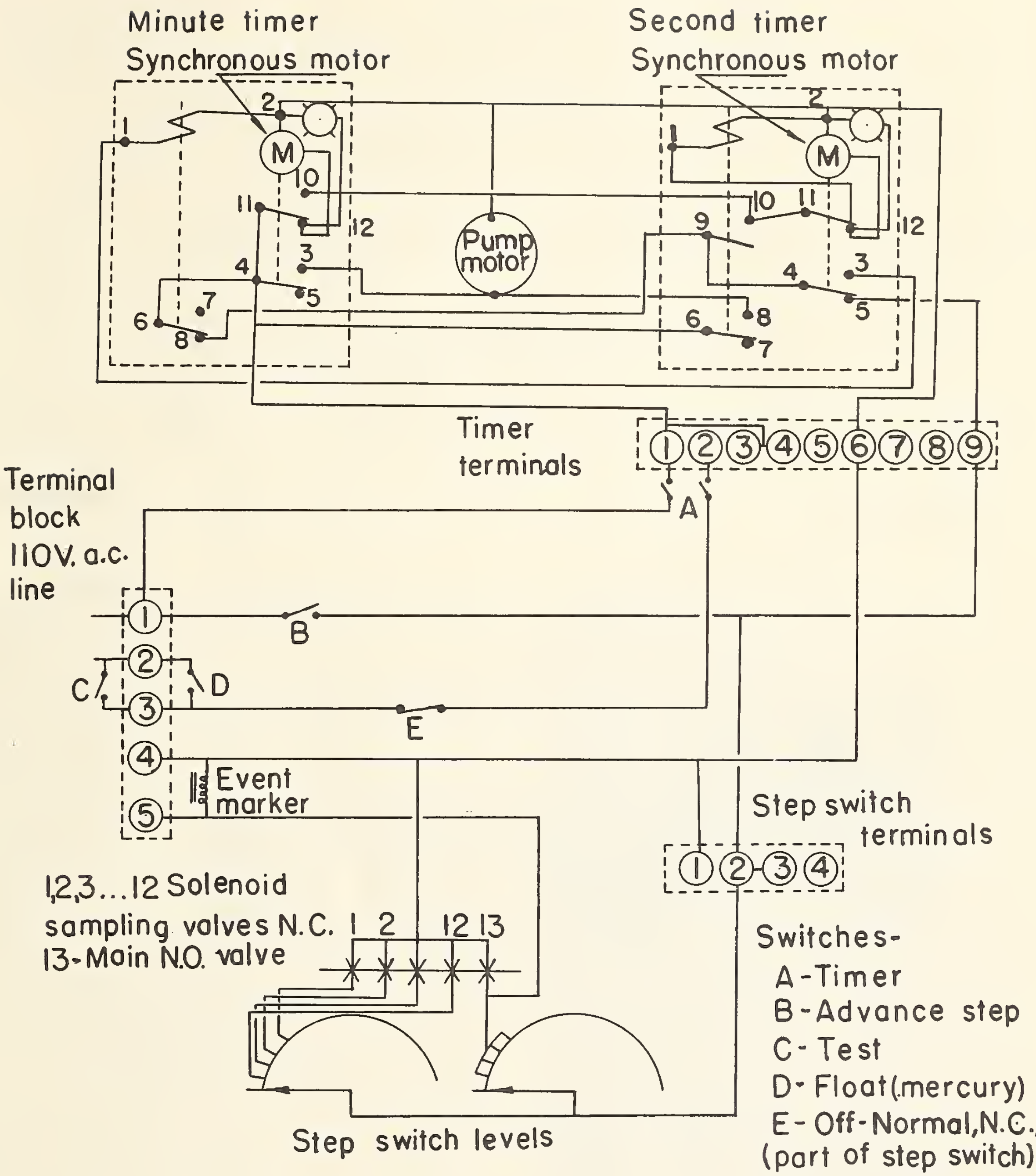


Figure 4.--Wiring using minute timer to delay start of flushing cycle. Timer modification procedure: Unsolder wire from No. 10 relay contact inside case and resolder to N.O. (normally open) contact (vacant) on the inside microswitch of the minute timer. Set 4-3 contacts of second timer to lead 11-12 contacts by ½ second. Set 4-3 contacts of minute timer to lead 11-12 contacts by 20 to 30 seconds.

Part and manufacturer	Price, 1968
Type 45 rotary step switch, Cat. #RW-18	$39.55
Automatic Electric Co., 2801 Far Hills Ave., Dayton, Ohio 45419	
Skinner electric valves, Cat. #V52LA3012, 3/8" NPT (each).	12.00
Tube fittings, black polyethylene tubing, and pipe fittings for valves	[1]30.00
Skinner Electric Valve Division, Skinner Precision Industries, Inc., 95 Edgewood Ave., New Britain, Conn. 06050	
Miscellaneous: Hardward, terminal block, switches, wire, lugs, and so forth	[1]15.00

[1] Estimated.

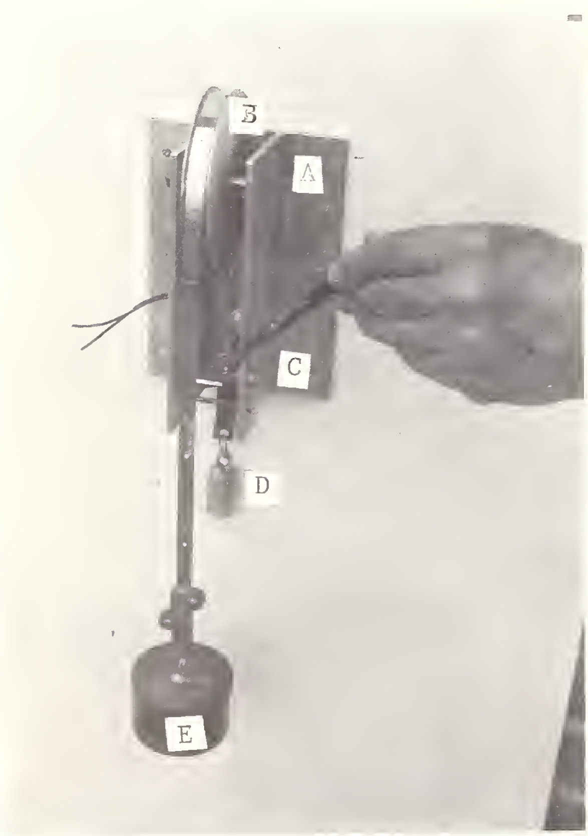


Figure 5.--"On-off" switch. A, Support channel; B, float tape pulley; C, mercury switch on tilt plate; D, counterweight; and E, float.

2. The "on-off" switch shown in figures 5 and 6 has a definite advantage over the liquid level switch shown in figure 4 of ARS 41-136. The desire for more precise "turn-off" points led to the design of a float-actuated, tilting, mercury, liquid level switch. The mercury switch is mounted above the stilling well on a pivoted aluminum tilt plate between the legs of an aluminum channel; it is limited in movement by two brass bolts, which act as stops. The float tape pulley is mounted above the switch in such a manner that the counterweight clamp operates the mercury switch. An increase in depth of runoff water in the measuring flume causes the float to rise and the counterweight to drop, allowing the end of the tilt plate to fall and the mercury to flow to the contact end or "on" position. A water surface rise of 0.02 foot is necessary to tilt the mercury switch enough to make electrical contact. When the water depth in the flume drops, the counterweight lifts the end of the tilt plate so that the mercury flows away from the contacts and the current is broken. The exact depths at which the switch opens and closes are determined by in-place calibration.

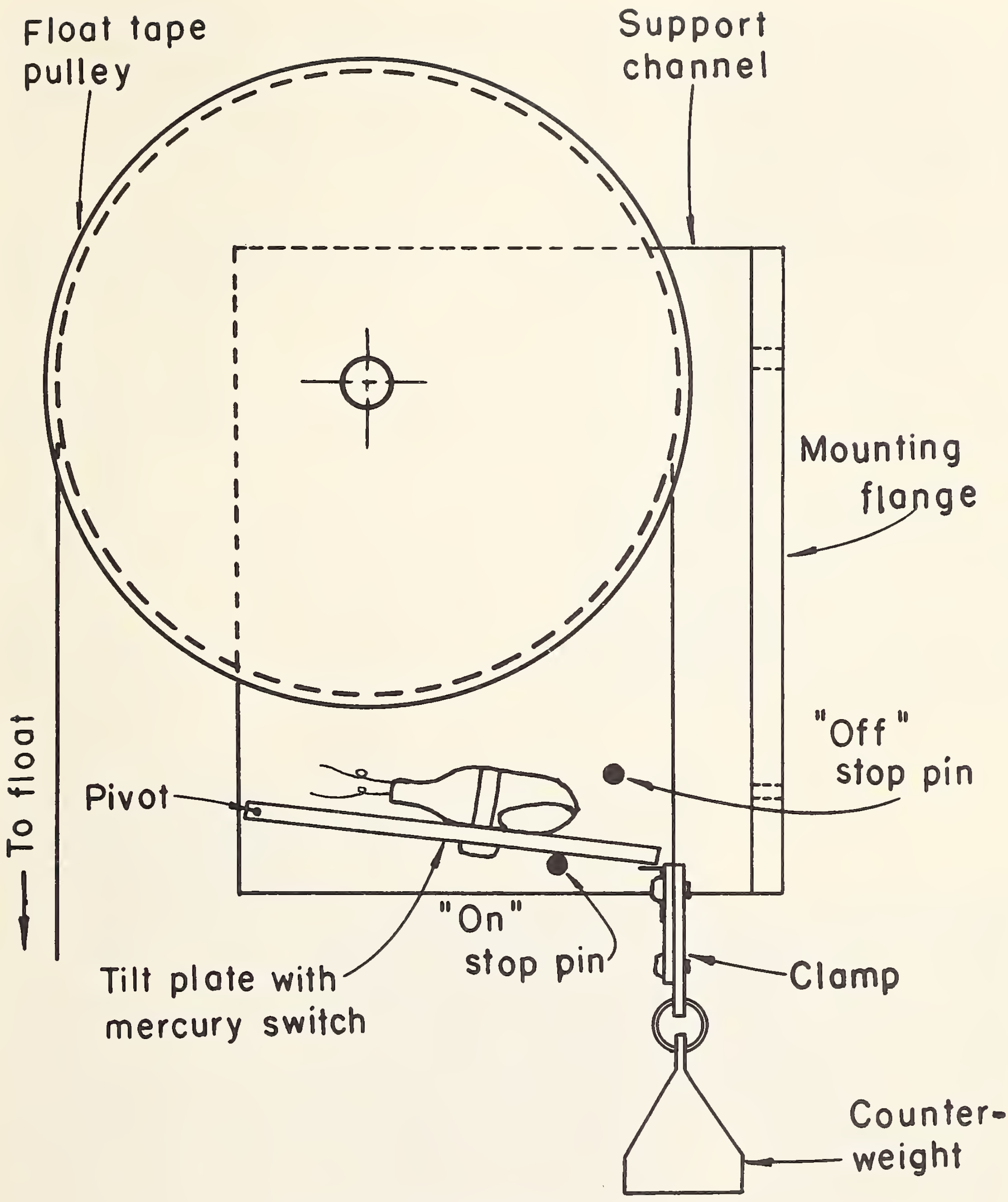


Figure 6.--Construction details of "on-off" switch.

If the "on" position is set for a depth of 0.10 foot, the "off" position will be 0.02 foot lower, or at 0.08 foot. The required operation will be performed repeatedly at these settings--within an 0.01 foot error. Construction details are given in figure 6.

3. A weep hole in the wall of the stilling well at about 0.02 foot below zero flow depth allows water to seep out slowly and cause the float for the on-off switch to fall and stop the pump system at the end of storm runoff. Thus a positive cutoff point is reached. Without the weep hole, sediment blocked the stilling well intake openings, holding the water level above the "off" point even though there was no water in the flume to be sampled. The pump ran without water and was severely damaged.

4. Intake sampling tube ports in the bottom side of the 1/2-inch ID stainless steel sampling tube (figs. 2, 7, 8) were enlarged to slots 1 inch long and 1/4 inch wide and covered with copper window screen cages. The screen extends out from the port opening in the form of a blister to provide a larger intake area, less susceptible to clogging with organic debris in the runoff water (fig. 8).

5. Event marker installed on an FW-1 water level recorder (fig. 9) makes 1/8-inch-long vertical marks on the bottom margin of the chart each time a sample is taken. Without the event marker, the exact time of sampling and, therefore, the exact flow rate for each sample could not always be determined.

The event marking pen and water level recording pen are set on the same time line on the hydrograph chart. The zero depth level is transposed upward to the 0.1-foot scale line on the chart to allow space at the bottom of the chart for the event marker.

The event marker consists of a capillary pen point and arm mounted on a 110-volt a.c. electromagnetic relay from which the contact points have been removed (fig. 9). Flexible polyethylene capillary tubing leads from an ink reservoir, glued to the recorder base, to the pen point. The sudden vertical movement of the pen when marking the sampling event is accomplished neatly with this equipment. If a common pen in which the liquid ink supply is stored in the pen point were used, ink would splatter on the chart.

The coil of the electromagnetic is wired parallel to the main valve in the return line of the pumping system (figs. 2 and 4). Therefore, when the

Figure 7.--Sample intake system in water. A, Suction tube leading to pump; B, anchor; C, intake sampling tube; and D, float.

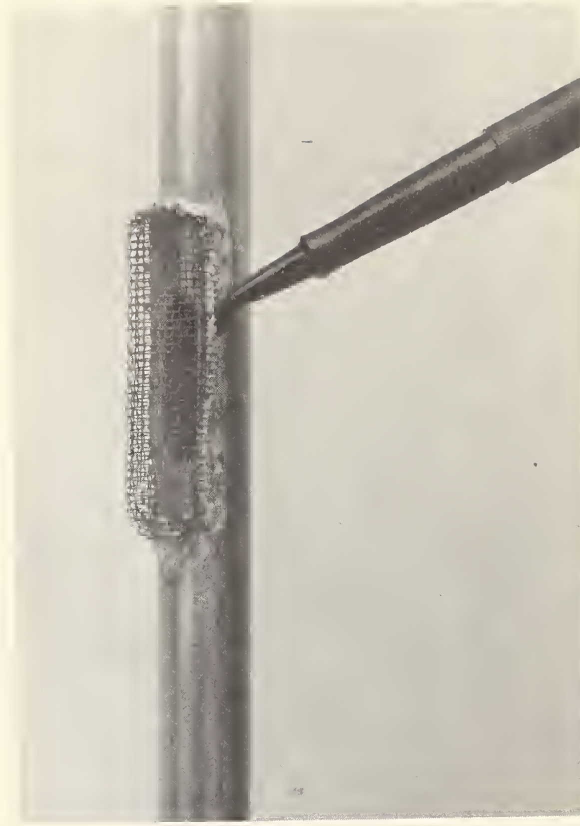


Figure 8.--Intake sampling tube port with screen wire trash guard.

Figure 9.--Sample event marker on water-stage recorder. A, Capillary pen point; B, 110-volt a.c. electromagnetic relay without contact points; C, ink reservoir with No. 22 plastic capillary tube; D, flood stage graph; and E, sample event marks.

circuit is energized, one of the 12 sample valves opens; the main valve closes, diverting the pumped flow into a sample jug; and the event marker makes its mark. By following the time line from this mark on the base line of the chart to the water depth line, the exact time and water depth at which each sample was taken can be readily determined.

SAMPLING EQUIPMENT AND ITS OPERATION

Equipment

Features of the automatic sampling equipment that have proven to be satisfactory are described below.

1. Intake sampling tube in rate-measuring flume (fig. 7) made in shop. Sampling tube (1/2 inch ID stainless steel) is pivoted at anchor mounted in floor near upstream end of flume. Float attached to downstream end of this tube rises as water depth increases. Intake sampling tube ports were described before (p. 8 and fig. 8). One port is at float end of tube and other two are one-third and two-thirds down the length of the tube.

2. Twelve solenoid valves (fig. 10) deliver water sample from pump system to collector jugs in 12-cubic-foot refrigerator (fig. 11). Another solenoid valve serves as main valve (fig. 2) in delivery system. When closed, the main valve diverts flow through one of the 12 sampling valves which is opened at same instant.

3. Step switch (figs. 4 and 12) transmits signals from timers to solenoid valves.

The liquid sampler has timing control features that are set to flush out the system, deliver to a 1-gallon glass jug a predetermined amount of water, and reflush system and sample at set intervals. The step switch also provides a means of lengthening the interval between samples by multiples of the initial interval.

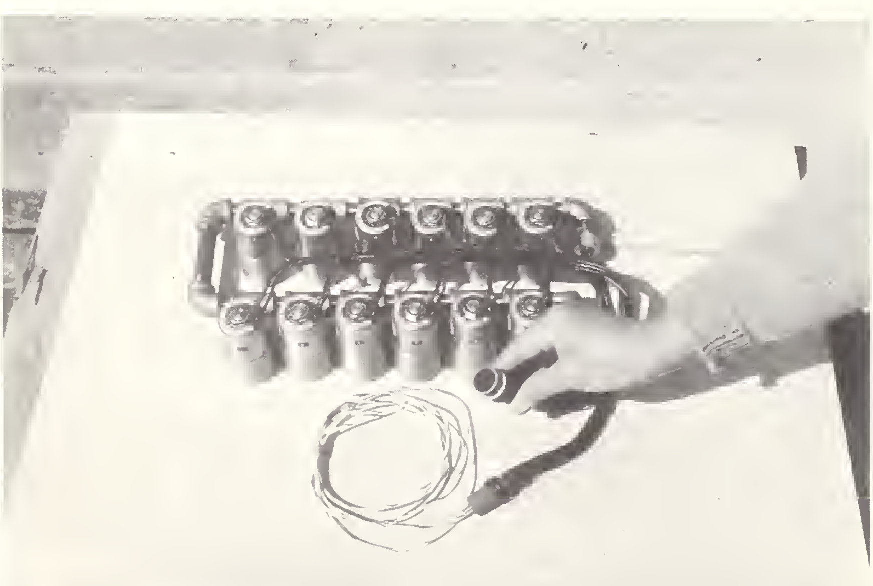
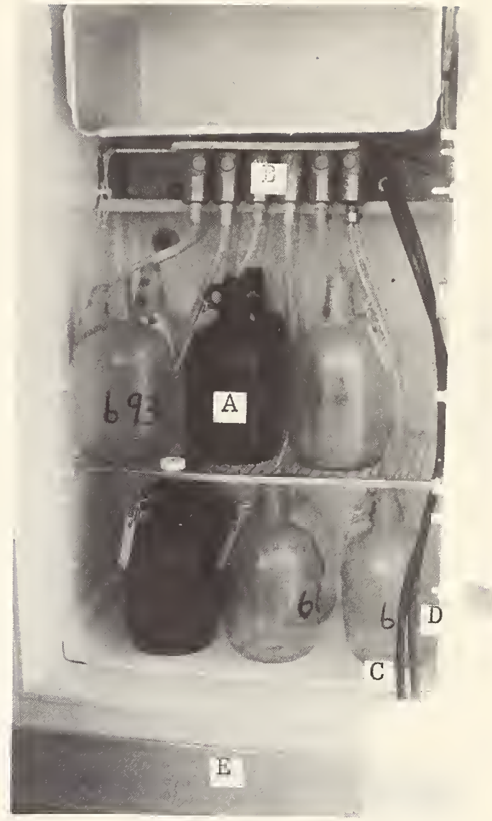


Figure 10.--Solenoid valve system designed to obtain 12 samples of runoff.

Figure 11.--One-gallon sampling jugs (A) and solenoid valve system (B) with exhaust (C) and supply hoses (D) in refrigerator (E) at sampling site.



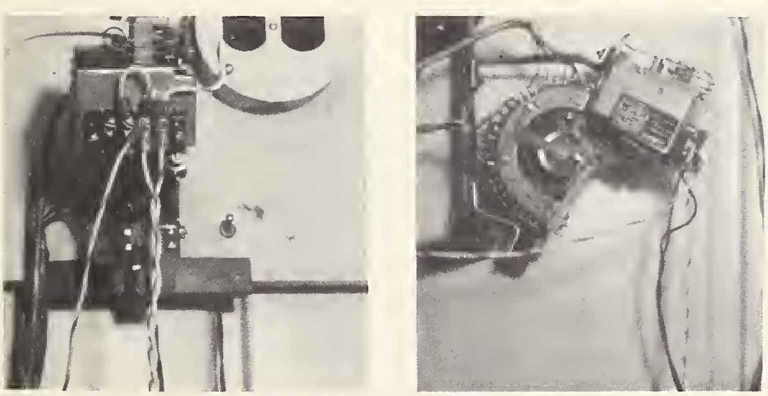


Figure 12.--Automatic switch consisting of terminal block, off-normal switch, and step switch.

Operation

The Coshocton station sampling program is operated as follows:

The mercury on-off switch (figs. 2, 5, 6) is set to actuate the minute timer when the flow reaches a depth sufficient to cover the intake ports and prevent air suction. The minute timer starts the pump and, with the main solenoid valve open and the sampling solenoid valves closed, the system is purged for 20 seconds. Then the main solenoid valve closes and the first of the sampling valves opens, permitting the first sample jar to be filled in about 18 seconds. The minute timer resets according to the preset time interval, at the end of which the sampling system is again purged and the second sample is taken. The timing, purging, and sampling phases are repeated until all sample jars have been filled or until the lowering runoff stage turns the mercury switch off--whichever comes first.

In order to start purging when the rising water depth causes the mercury switch to close, a portion of the initial time interval on the minute timer must be wasted. This is done while servicing the sampler prior to the next runoff event by closing the test switch (fig. 4), allowing the red hand on the minute timer to advance to the 20-second mark on the dial. The test switch is then returned to the open position, which cuts off the power to the system.

Without this prerunoff wasting of the initial timing phase of the cycle, there would be a 3-minute delay instead of a 20-second delay between activation by runoff and the taking of the first sample. The characteristics of the watersheds, rainfall, and sampling problem at Coshocton make the 3-minute delay undesirable.

A constant interval of 3 minutes between successive samples throughout the entire flow period is unnecessary. The interval can be lengthened during the latter part of the flow period, when flow rates and concentrations of pollutants are more constant. The interval is lengthened by skipping certain positions on the step switch that selects the solenoid valves to be opened in sequence. By connecting the 12 valves to terminals 1, 2, 3, 4, 5, 7, 9, 11, 13, 17, 21, and 25, the time interval between samples becomes 3, 3, 3, 3, 6, 6, 6, 6, 12, 12, and 12 minutes, respectively.

Flow rates during the winter and early spring are lower and more uniform than those during the summer. Since they also persist longer, the sampling time sequence should be changed accordingly. This can be done very easily on the existing equipment by lengthening the setting on the timer dial (A of fig. 3) from a 3-minute interval to the desired time interval. For example, if a 10-minute interval is selected, the sampling time sequence then becomes 10, 10, 10, 10, 20, 20, 20, 20, 40, 40, and 40 minutes.

The test switch shorting out the mercury on-off switch and an advancing switch to pulse the step switch (fig. 4) enable field checking of the equipment and preparing it for automatic operation. The advancing switch is operated the number of times necessary to move the step switch to the starting point. The purge duration pointer (red hand) on the timer interval control is advanced to 20 seconds as described above.

The off-normal switch (E of fig. 4) normally closed (N.C.) is set to stop the entire system after the last jug (No. 12) is filled. No more samples can be obtained even though the water level switch is still closed. The system will have to be serviced by replacing the filled jugs with empty ones, back flushing the tubes, recycling the step switch, and advancing the minute timer.

Storm checks on operation of the system are desirable. Periodic hand samples are collected by holding a gallon jug in the streamflow at the flume outlet at the same time the automatic system is delivering a sample to the jug. The flow depth and time are marked on the water-stage recorder graph at this same time. Both the hand and the automatic sample jugs are labeled so that the results of laboratory analyses can be compared.

Servicing the system, after a storm runoff period, is accomplished as follows:

(1) Remove all jugs containing samples and make complete notes of jug number and sample sequence number of each.

(2) Measure depth of sediment on floor of flume and its paved approach area and compute volume. Place samples of this material in Teflon bags and freeze them preparatory to delivery for laboratory analysis. (This material is considered as transported off the gaged watershed.) Remove all sediment from this paved area.

(3) Disconnect suction tube between intake sampling tube and pump.

(4) Place suction end of this separation into can of clean water and pump through system and into spare jug placed at position No. 1.

(5) Force clean water back through suction tube and intake sampling tube to flush out foreign material.

(6) Reassemble suction line, taking care to make each joint airtight. If there are air leaks between pump and intake sampling tube, the sampling system will not operate.

(7) Open test shorting switch and close advancing switch to set step switch at initial point.

(8) Close test shorting switch to advance time to point of start of purging cycle.

(9) Remove spare jug at position No. 1 and insert clean jugs at all positions.

SAMPLING INSTALLATION

A complete layout of a sampling installation appears in figure 13. The runoff measuring flume (D) with shelter (C) for water-stage recorder has been in operation since June 1939 on this 2.68-acre cropped watershed. The average land slope is 13.6 percent. The precalibrated sheet metal flume is H-type; it is 3 feet deep and has a flow rate capacity of 30 c.f.s. Maximum flow depth through this flume was 1.63 feet (7.51 c.f.s.) in June 1940.

Figure 13.--Runoff measuring and sampling installation, looking downhill from experimental watershed: A, switchbox for electric power; B, shelter for refrigerator, sampler pump, and controls; C, shelter for water-stage recorder, and stilling well for float and mercury on-off switch; D, runoff rate measuring flume; E, intake sampling tube; F, purge discharge line from pump.

Total cost of the automatic sampling device at this installation in 1966 was approximately $3,000, including equipment, materials, and labor. With the above-mentioned modifications to the system, a comparable sampling setup can now be assembled for $1,200. This does not include the cost of the flume and water-stage recorder.

EVALUATION OF SAMPLING EQUIPMENT

The sampling equipment described in ARS 41-136 was installed on two watersheds at Coshocton in the spring of 1966. Improvements described in this report were made on the sampling equipment in 1968. One watershed, containing 2.68 acres with an average slope of 13.6 percent, was treated with 200 pounds per acre each of nitrogen, phosphorus, and potassium incorporated into the plow depth and 5 pounds per acre of dieldrin incorporated into the surface 3 inches of soil. Another watershed, containing 7.59 acres with an average slope of 15.8 percent, was used as a control with no dieldrin and no fertilizer plowed down. Corn was grown on both watersheds in 1966, followed by wheat in 1967 and meadow in 1968 and 1969.

Although 1966 rainfall during the growing season was adequate for crop growth, it did not follow the normal distribution pattern. No storm occurred that caused significant runoff from the treated watershed. Two sets of runoff samples were obtained from the untreated watershed, which was more susceptible to erosion than the smaller treated watershed. These samples were collected simultaneously several times during the storm. The percent solids was determined for those samples obtained from the automatic equipment and plotted as a function of time in figure 14. Only a few hand samples were taken--all at concentrations less than 0.6 percent. The composition of almost all the automatic samples agreed with that of the hand samples within 0.05 percent concentration.

Distribution of flow rates with time was typical of runoff from intense summer storms. Distribution of solids in the runoff, as determined from five samples at 3-minute intervals followed by two at 6-minute intervals was about as expected--high concentrations during the first part of the runoff and diminishing during the period of lessening flow rates.

In 1968, five watersheds were instrumented with the improved automatic samplers, which operated successfully in more than 30 runoff events with moderate sediment concentrations. However, under extreme loads of coarse sediment, the sampling valves occasionally failed to seat properly, causing certain sample jars to overflow and others to be only partially filled.

Inspection of sampling equipment during storm periods is very desirable. Performance can be checked and adjustments made if necessary.

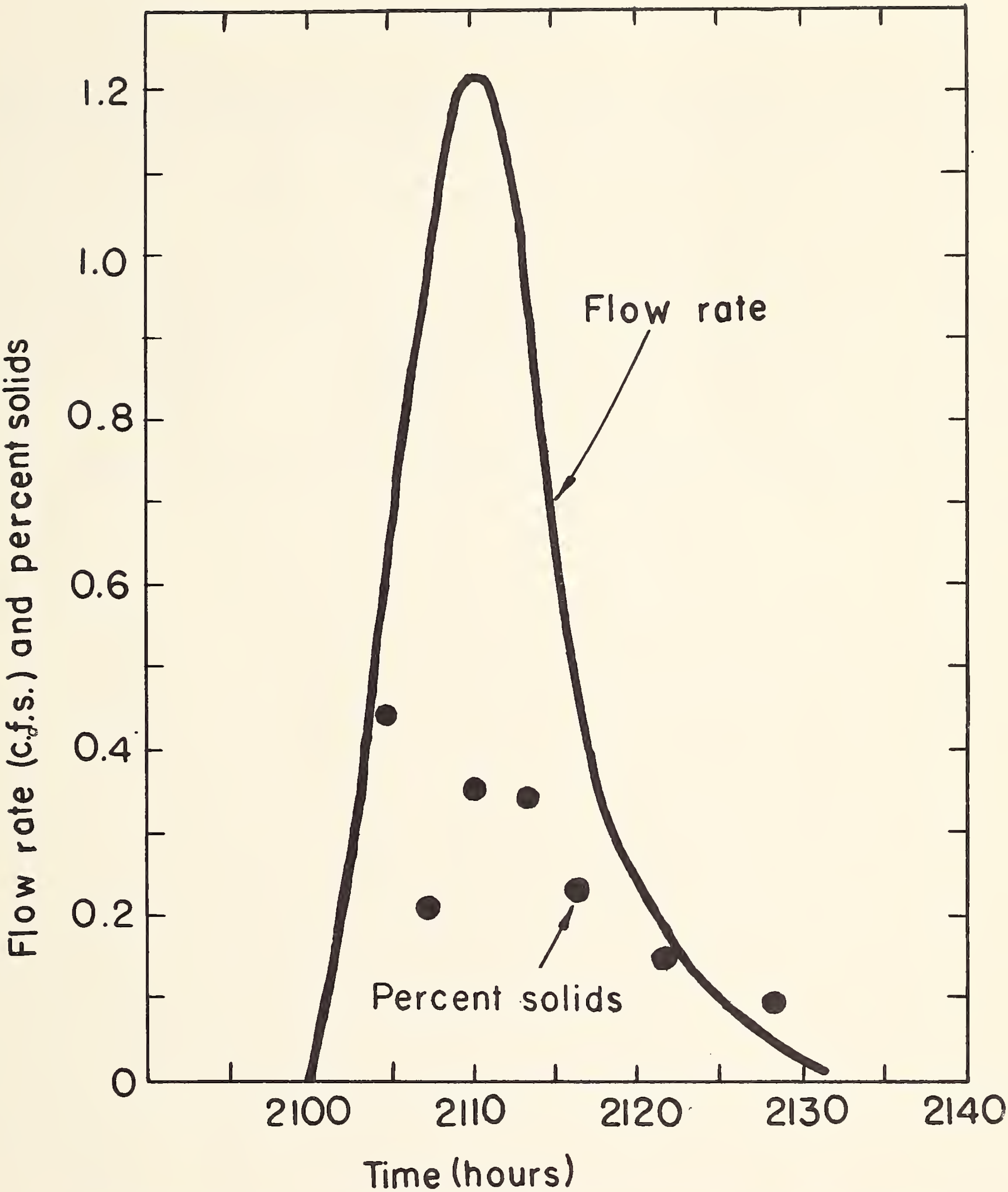


Figure 14.--Flow rate and percent solids in runoff on 7.59-acre watershed, September 3, 1966.

SUMMARY

Great care must be exercised in collecting, preparing, and storing runoff samples to be used in studying the loss of pesticides and other chemicals from agricultural lands. Several individual samples must be collected at variable predetermined time intervals throughout the runoff hydrograph of each storm. Each sample must be related to runoff rate at the time of sampling.

A detailed description is presented of the construction and operation of automatic sampling equipment installed on experimental watersheds at Coshocton, Ohio. The equipment is designed to operate unattended. It remains on a standby basis and initiates a predetermined sampling sequence at the onset of runoff from the watershed. Samples are collected in 1-gallon glass jugs, which are stored in a refrigerator. The sampling mechanism turns itself off after the total number of samples is collected or if runoff stops before this.

This composition of samples collected by the automatic equipment compares very favorably with that of samples collected by hand from below the flume.

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